

## WHAT IS CLAIMED IS:

- 1     1.     A system, comprising:  
2             a computer configured to determine a position and shape of an object of  
3     interest from video images and characterize activity of said object of interest  
4     based on analysis of changes in said position and said shape over time.
- 1     2.     The system of claim 1, further comprising:  
2             a video camera coupled to said computer for providing said video images.
- 1     3.     The system of claim 2, further comprising:  
2             a video digitization unit couple to said video camera and said computer  
3     for converting said video images provided by said video camera from analog to  
4     digital format.
- 1     4.     The system of claim 3, further comprising:  
2             a storage/retrieval unit coupled to said video digitization unit, said video  
3     camera, and said computer, for storing said video images and standard object  
4     video images.

1 5. The system of claim 1, wherein said computer includes an object  
2 identification and segregation module receiving said video images.

1 6. The system of claim 5, wherein said object identification and segregation  
2 module operates using a background subtraction algorithm in which a plurality  
3 of said video images are grouped into a set, a standard deviation map of the set  
4 of video images is created, a bounding box where a variation is greater than a  
5 predetermined threshold is remove from said set of video images, and the set of  
6 images less said bounding boxes is averaged to produce a background image.

1 7. The system of claim 6, wherein said computer further includes a behavior  
2 identification module for characterizing activity of said object, said behavior  
3 identification module being coupled to said object identification and segregation  
4 module.

1 8. The system of claim 7, wherein said computer further includes an object  
2 tracking module for tracking said object from one frame of said video images to  
3 another frame, and an object shape and location change classifier for classifying

4 the activity of said object, coupled to each other, said object identification and  
5 segregation module, and said behavior identification module.

1 9. The system of claim 8, wherein said computer further includes a standard  
2 object behavior storage module that stores information about known behavior of  
3 a predetermined standard object for comparing the activity of said object, said  
4 standard object behavior storage module being coupled to said behavior  
5 identification module, and a standard object classifier module coupled to said  
6 standard object behavior module.

1 10. The system of claim 5, wherein said computer further includes a standard  
2 object behavior storage module that stores information about known behavior of  
3 a predetermined standard object for comparing the activity of said object, said  
4 standard object behavior storage module being coupled to said behavior  
5 identification module.

1 11. The system of claim 1, wherein said object is a living object.

1 12. The system of claim 1, wherein said object is an animal.

1 13. The system of claim 1, wherein said object is a mouse.

1 14. The system of claim 1, wherein said object is a human.

1 15. The system of claim 1, wherein said object is a man made machine.

1 16. A method of determining and characterizing activity of an object using  
2 computer processing of video images, comprising the steps of:

3 detecting a foreground object of interest in said video images;

4 tracking changes to said foreground object over a plurality of said video  
5 images;

6 identifying and classifying said changes to said foreground object; and

7 characterizing said activity of said foreground object based on comparison  
8 to activity of a standard object.

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1 17. The method of claim 16, wherein said step of characterizing said activity  
2 includes the steps of:

3 describing a sequence of postures as behavior primitives; and

4 aggregating behavior primitives into actual behavior over a range of  
5 images.

1 18. The method of claim 16, wherein said foreground object detection  
2 includes the step of generating a background image from an average of a set of  
3 individual frames of said video images.

1 19. The method of claim 18, wherein said step of generating a background  
2 image includes the step of determining variation in intensity of pixels within said  
3 individual frames to identify a region where said foreground object is located.

1 20. The method of claim 19, wherein said step of generating a background  
2 image further includes the step of using non-variant pixels of the video images  
3 to generate said background image.

1 21. The method of claim 20, wherein said step of generating a background  
2 image is performed periodically to correct for changes in background objects and  
3 small movements of a camera capturing said video images.

1 22. The method of claim 16, wherein said detecting a foreground object

2 includes using a background subtraction method comprising the steps of:  
3 multiply frames in a neighborhood of current image;  
4 apply a lenient threshold on a difference between a current image and a  
5 background so as to determine a broad region of interest;  
6 classify by intensity various pixels in said region of interest to obtain said  
7 foreground object; and  
8 apply edge information to refine contours of said foreground object  
9 image.

1 23. The method of claim 16, wherein said step of detecting said foreground  
2 includes the step of manual identification of foreground objects to be tracked and  
3 characterized.

1 24. The method of claim 17, wherein said posture determination and  
2 description includes using statistical and contour-based shape information.

1 25. The method of claim 24, wherein said step of identifying and classifying  
2 changes to said foreground object includes using statistical shape information  
3 selected from the group consisting of:  
4 area of the foreground object;  
5 centroid of the foreground object;

6 bounding box and its aspect ratio of the foreground object;  
7 eccentricity of the foreground object; and  
8 a directional orientation of the foreground object relative to an axis as  
9 generated with a Principal Component Analysis.

1 26. The method of claim 24, wherein said step of identifying and classifying  
2 changes to said foreground object uses contour-based shape information selected  
3 from the group consisting of b-spline representation, convex hull representation,  
4 and corner points.

1 27. The method of claim 24, wherein said step of identifying and classifying  
2 changes to said foreground object includes identifying a set of model postures and  
3 their description information, said set of model postures including horizontal  
4 posture, vertical posture, eating posture, or sleeping posture.

1 28. The method of claim 27, wherein said step of identifying and classifying  
2 changes to said foreground object includes classifying the statistical and contour-  
3 based shape information from a current image to assign a best-matched posture.

1 29. The method of claim 17, wherein the said step of describing said behavior  
2 primitives includes the step of identifying patterns of postures over a sequence of  
3 images.

1 30. The method of claim 29, wherein said step of describing said behavior  
2 primitives step further includes the step of analyzing temporal information  
3 selected from the group consisting of direction and magnitude of movement of  
4 the centroid, increase and decrease of the eccentricity, increase and decrease of  
5 the area, increase and decrease of the aspect ratio of the bounding box, change in  
6 the b-spline representation points, change in the convex hull points, and direction  
7 and magnitude of corner points.

1 31. The method of claim 29, wherein the step of describing said behavior  
2 primitives step includes behavior of a standard object such as stationary, moving  
3 for left to right and vice versa, standing up, and falling down.

1 32. The method of claim 29, wherein the step of describing said behavior  
2 primitives step includes a step for providing a means for entering user defined  
3 customized behavior primitives.



1 33. The method of claim 17, wherein the said step of determining actual  
2 behavior by aggregating behavior primitives includes the step of analyzing  
3 temporal ordering of the primitives, such as using information about a transition  
4 from a previous behavior primitive to a next behavior primitive.

1 34. The method of claim 33, wherein said temporal analysis is a time-series  
2 analysis such as Hidden Markov Model (HMMs).

1 35. The method of claim 33, wherein the said step of determining actual  
2 behavior includes identifying actual behavior selected from a group consisting of  
3 sleeping, eating, roaming around, grooming, and climbing.

1 36. A method for background subtraction of a video image, comprising the  
2 steps of:

3 grouping a number of images into a set of video images;  
4 creating a standard deviation map of the grouped images;  
5 removing a bounding box area of said image where variation is above a  
6 predetermined threshold to create a partial image; and

7 combining said partial image with an existing set of partial images by  
8 averaging the set of images to generate a complete background image deplete of  
9 a desired foreground object.

1 37. The method of claim 36, further comprising the step of subtracting said  
2 complete background image from a current image so as to obtain said desired  
3 foreground object.

1 38. The method of claim 36, wherein said steps are repeated periodically to  
2 update said complete background image.

1 39. A system, comprising:  
2 a computer configured to detect and characterize at least a single behavior  
3 of an object of interest based on movement of said object, using video image  
4 analysis.

1 40. The system of claim 39, wherein said object is an animal and said  
2 behavior is detecting when said animal is freezing or a touch or sniff of a  
3 particular item.

1 41. The system of claim 39, wherein said object is an animal and said  
2 detecting and characterizing said behavior is determined by comparing behavior  
3 of said animal against a predetermined norm.

1 42. The system of claim 39, wherein said object is an animal and  
2 characterizing said behavior is determined by analyzing a daily pattern of said  
3 object against a statistical norm so as to detect effects of drugs or genetic  
4 manipulations on said animal.